United States Patent [19]

Almström

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[54] **SOLAR ENERGY CONVERSION PLANT**

[75] Inventor: **Sten-Hakan Almström,** Lund, Sweden

[73] Assignee: **United Stirling AB,** Sweden

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[51] **Int. Cl.**[3] **F02G 1/04;** F02G 1/06

[52] **U.S. Cl.** **60/641.14;** 60/521; 60/525; 60/698

[58] **Field of Search** 60/517, 525, 521, 522, 60/641.8, 524, 641.14, 698, 716, 718

[56] **References Cited**

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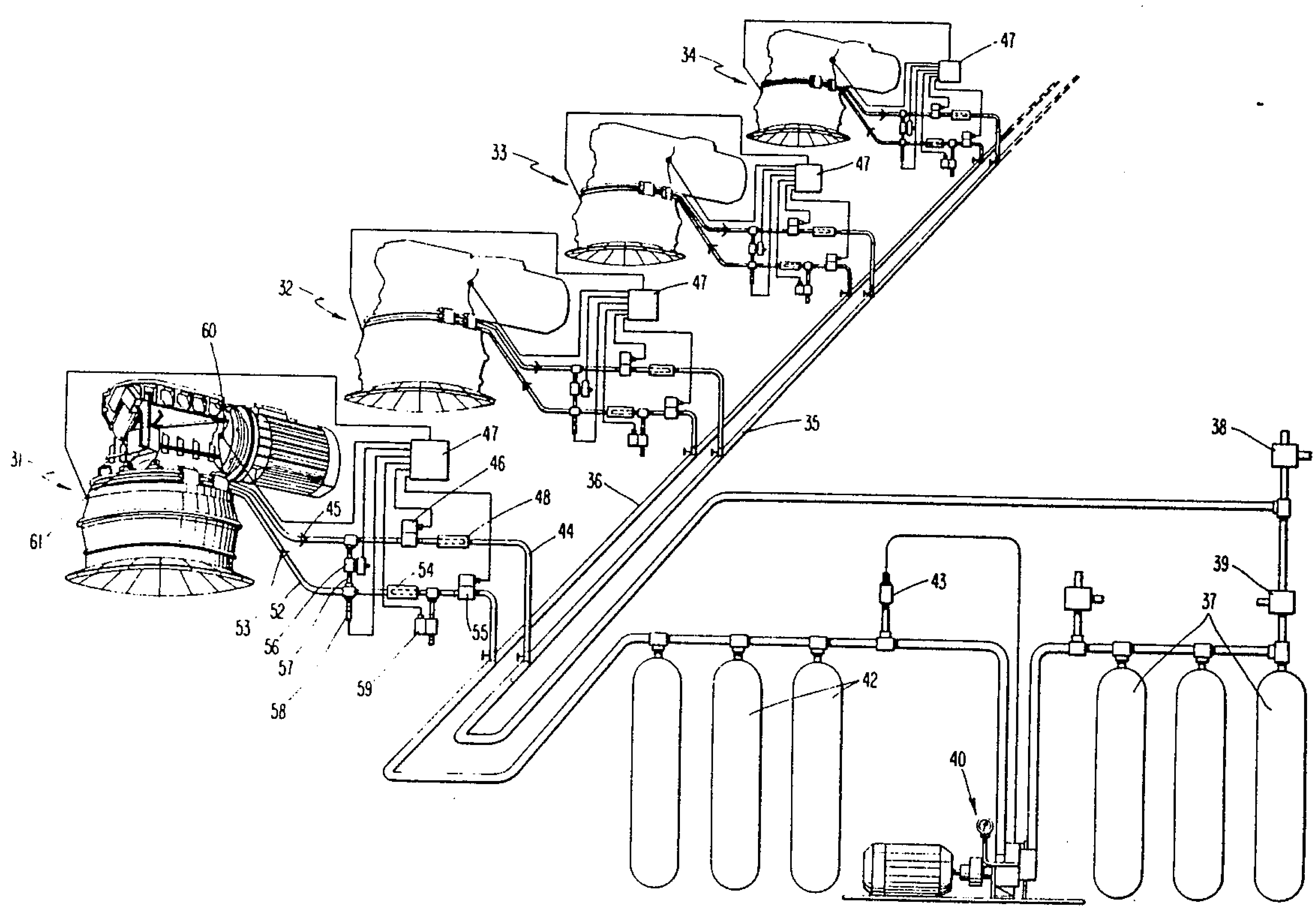
Primary Examiner—Allen M. Ostrager

Attorney, Agent, or Firm—Finnegan, Henderson, Farabow, Garrett & Dunner

[57] **ABSTRACT**

A solar energy conversion plant is composed of a number of conversion units. Each unit is a hot gas engine coupled to a generator. All hot gas engines are connected to common tube mains one of which contains working gas of high pressure while another contains gas of low pressure. A compressor is arranged to maintain the pressures in the mains and is separately governed.

4 Claims, 2 Drawing Figures



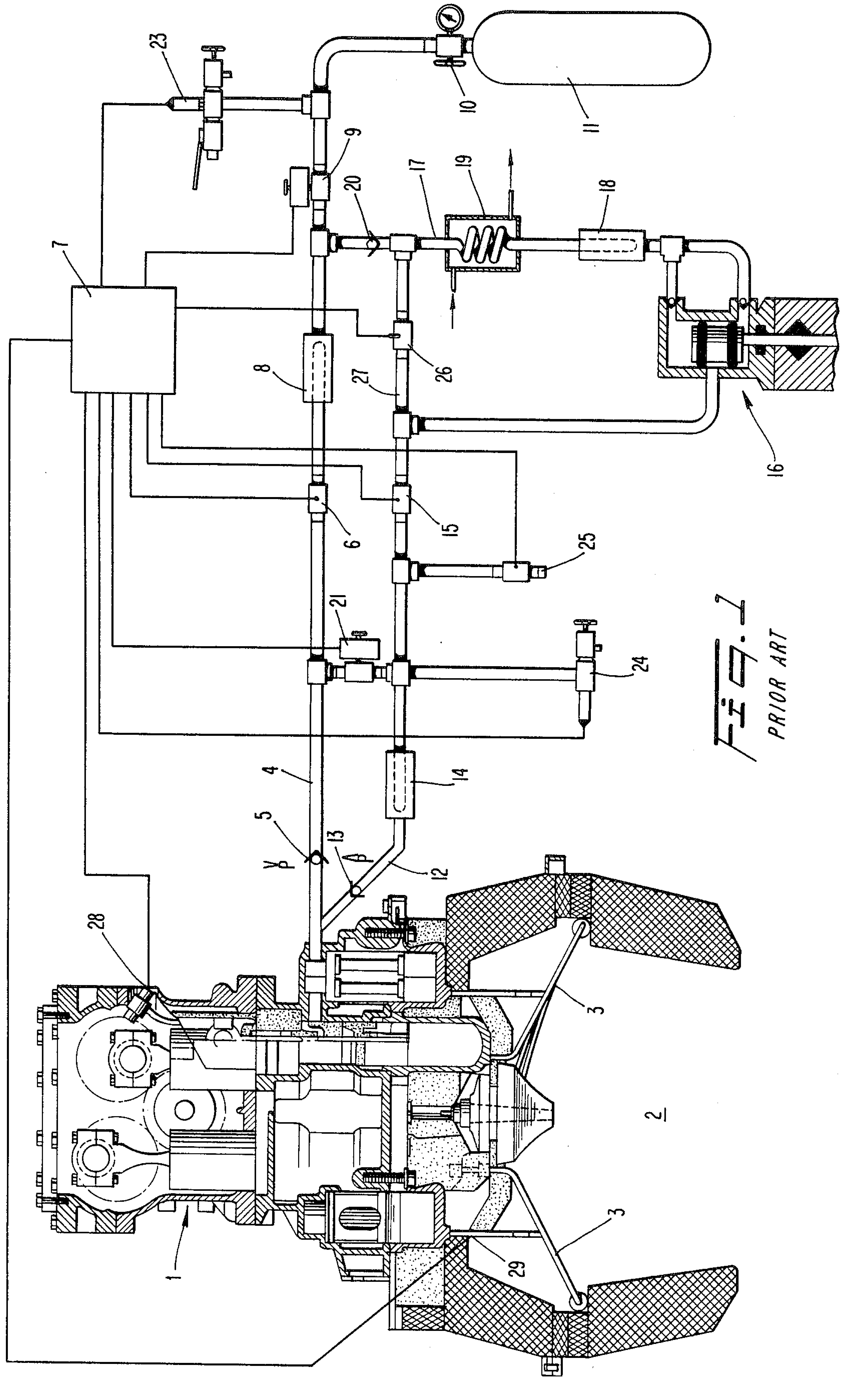


FIG. 1
PRIOR ART

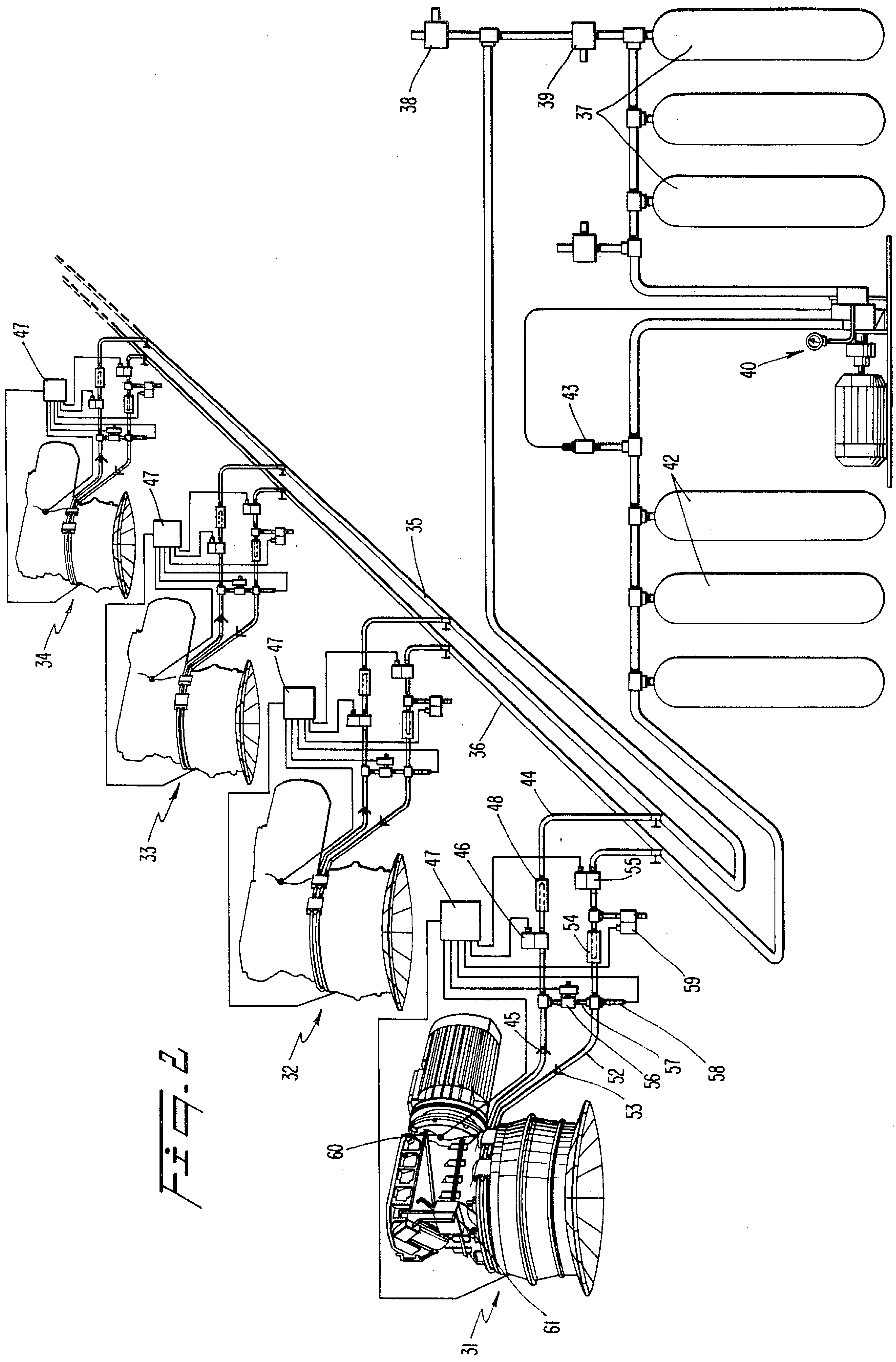

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FIG. 2

SOLAR ENERGY CONVERSION PLANT

PRIOR ART DISCLOSURE

"Design Study of a Kinematic Stirling Engine for Dispersed Solar Electric Power Systems".

Report No DOE/NASA/0056-79/2 NASA CR-159588.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a solar energy conversion plant comprising a plurality of solar heated, closed-cycle hot gas engines.

2. Description of the Prior Art

Solar energy conversion plants of the above type have hitherto been composed of a number of individual engines, each engine being provided with a control system for supplying gas to, or removing gas from, its working gas charges, and with a compressor provided for sucking gas from a low pressure tube system to a high pressure tube system including a high pressure gas reservoir.

In known conversion plants, each compressor has been directly coupled to the shaft of the respective engine and thus all the compressors-the number of which corresponds to the number of engines in the plant ran continuously.

Also each engine must be provided with two safety valves in order to avoid excessive gas pressure in case the pressure regulating valves should fail in operation.

SUMMARY OF THE INVENTION

The object of the present invention is to provide a solar energy conversion plant having a plurality of closed cycle, hot gas engines in which the overall gas control system has been simplified to reduce initial capital outlay as well as maintenance costs and to obtain increased reliability.

The conversion plant is in accordance with the invention characterised in that all engines of the plant are connected to be supplied with high pressure working gas from a first tube main, which is in turn supplied from a high pressure gas reservoir, and are connected to dump working gas to a second tube main, and a common, separately driven compressor operatively connected to deliver gas from the second tube main to the high pressure gas reservoir. The connection between the first two main and the high pressure reservoir can be through a pressure reduction valve.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a gas pressure control system of known design adapted to a single engine plant and

FIG. 2 shows a solar conversion system according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIG. 1 a solar powered Stirling engine of known design has been generally designated by the reference numeral **1**. At the lower part of the engine concentrated solar radiation is passed upwards through an aperture **2** and causes heating of tubes **3** containing engine working gas. At a given speed of the engine the pressure of the working gas determines the torque and thus the engine power output. Gas is supplied via a first tube **4** containing a check valve **5** allowing flow of gas only in the direction into the engine. Said first tube **4** also contains a supply solenoïd valve **6** governed by a digital control unit 7. The tube **4** which also contains a filter **8**, a shut-off solenoid valve **9** and a manual shut-off valve **10** is connected to a high pressure gas reservoir **11**.

A second tube designated by the reference numeral **12** contains a check valve **13** allowing flow of gas in the direction out of the engine **1** only. Said second tube **12** contains a filter **14** and a dump solenoid valve **15** and is connected to the suction side of a double-acting compressor **16** the delivery side of which is connected to the said first tube **4** via a further tube **17**. The further tube **17** contains a filter **18**, a cooler **19** and a check valve **20**. An emergency short-circuiting solenoid valve **21** is provided in a tube **22** connecting said first and second tubes **4** and **12** respectively. A first safety valve **23** is provided in the tube **4** between the valves **9** and **10** and a second safety valve **24** as well as an external dumping solenoid valve **25** is mounted in the tube **12** between the filter **14** and the dump solenoid valve **15**.

A compressor short-circuiting valve **26** is mounted in a tube **27** connecting the suction and the delivery side of the compressor. Together with the valve **6** also the valves **9**, **15**, **21**, **23**, **24**, **25** and **26** are governed by the control unit **7**. A speed transducer **28** and a thermocouple **29** are also connected to the unit **7**.

The known device illustrated in FIG. **1** and described above will operate basically as follows:

In case the solar radiation increases the temperature of the hot gas engine tubes **3** will increase and the thermocouple **29** will give a corresponding signal to the control unit **7**. Said unit **7** will now cause an opening of the supply solenoid valve **6**. Gas will enter into the engine and cause a higher mean pressure of the working gas and a higher engine torque. The speed of the engine is constant because of its connection to an AC generator connected to an existing grid (not shown). However, the energy output is increased and thus the high temperature parts of the hot gas engine are correspondingly cooled so as to maintain a constant temperature in spite of the increase of solar energy input.

The valves **15** and **21** are closed when the solenoid supply valve **6** is open and gas will pass from the reservoir **11** into the engine. As soon as the desired temperature is obtained the valve **6** is closed. It may also be desired to decrease the amount of working gas in the engine in order to increase the temperature of the tubes **3** and this is obtained by opening the valve **15**. Gas may now pass via the tube **12** to the compressor **16** and from the compressor **16** to the reservoir **11**.

Excessive pressures in the reservoir **11** and the engine **1** are avoided by the safety valves **23** and **24** respectively. In case both valves **6** and **15** are closed—a quite normal case—the valve **26** may be opened and release the compressor **16**.

The valves **21** and **25** are emergency valves. The valve **21** will eliminate all power output from the engine by equalizing the working gas pressures in the engine. The valve **25** has the same effect by dumping the gas. The speed transducer **28** has been mounted for use in case the connection to the grid should be cut off.

A conversion plant according to the invention and shown in FIG. **2** comprises four Stirling engines **31**, **32**, **33** and **34** each being solar heated and coupled to electric generators. Only the Stirling engine **31** needs to be described as it is identical with the other engines of the plant.

The plant comprises a first tube main **35** and a second tube main **36**. The first tube main is connected to a high pressure gas reservoir **37** and contains a safety valve **38** and a pressure reduction valve **39** the latter being mounted close to the reservoir **37**. A compressor **40** driven by an electric motor delivers gas to the reservoir **37** a safety valve **41** being mounted in the tube connection between compressor and reservoir.

The second tube main **36** is connected to the suction side of the compressor **40** and is connected to a low pressure gas reservoir **42**. A pressure switch **43** is mounted in the second tube main **36** starting the compressor **40** as soon as the gas pressure in the tube main **36** exceeds a certain value.

The engine **31** is provided with a pressure control system having basically the same function as that described above with reference to FIG. **1**. However, the gas control system of the engine **31** has been simplified as will be understood from the description below.

A first tube **44** containing a check valve **45** allowing flow of gas only in the direction into the engine **31** has been connected to the first tube main **35**. Said first tube also contains a supply solenoid valve **46** governed by a digital control unit **47**. The tube **44** also contains a filter **48**.

A second tube **52** contains a check valve **53** allowing flow of gas only in the direction out of the engine **31**. Said second tube contains a filter **54** and a dump solenoid valve **55**. An emergency short-circuiting solenoid valve **56** is mounted in a tube **57** connecting the said first and second tubes **44** and **52**.

A maximum pressure transducer **58** and an external dumping solenoid valve **59** are also mounted in the second tube **52**. A speed transducer **60** and a thermocouple **61** are provided at the engine **31** and connected to the unit **47**.

The energy conversion plant according to the invention will operate as follows:

The part of the plant common to all engines **31-34** consists of the tube mains **35** and **36** as well as the compressor **40** and the reservoirs **37** and **42**.

The compressor **40** delivers gas to the reservoir **37** which is able to store gas at pressures above 20 MPa. The pressure reduction valve **39** ensures that the pressure in the tube main **35** remains about 12 MPa. The pressure switch **43** starts the compressor **40** as soon as the pressure in the second tube main **36** exceeds about 6 MPa.

Thus the gas pressures in the two tube mains **35** and **36** may be kept almost constant and due to the reservoirs **37** and **42** a rather small compressor **40** may be used for the purpose.

Each engine—e.g. the engine **31**—will operate as follows:

In case the thermocouple **61** calls for decrease in temperature and thus increased engine pressure the solenoid valve **46** is opened and gas supplied to the engine **31** from the first tube main **35**. As soon as the desired temperature is obtained the vvalve **46** is shut off again. Conversely the dump valve **55** is activated in case the engine temperature should be increased causing gas to flow from the engine into the second tube main **36**. At constant engine speed this will decrease the power output and thus increase the working gas temperature—at constant solar energy input.

For emergency stop of the engine it is necessary to be able to use either the short-circuiting valve **56** or the external dump valve **59**.

The provision of two tube mains **35**, **36** in which predetermined pressures are kept almost constant makes it possible to substantially decrease the number of valve functions at each engine of the plant.

I claim:

1. A solar energy conversion plant comprising a plurality of solar heated, closed-cycle hot gas engines, each engine being independently operable and being provided with a control system for introducing gas to or removing gas from its working gas charges; a common working gas supply system, said supply system including a high pressure working gas reservoir; a first tube main connected to be supplied working gas by said reservoir; a second tube main, wherein each engine control system is operatively connected to be supplied with high pressure working gas from said first tube main and to dump working gas to said second tube main; and a common, separately driven compressor operatively connected to deliver gas from said second tube main to said high pressure gas reservoir.

2. The solar energy conversion plant as in claim **1** wherein said first tube main is connected to said high pressure reservoir through a pressure reduction valve.

3. The solar energy conversion plant as in claim **1** further including a low pressure working gas reservoir connected to said second tube main.

4. The solar energy conversion plant as in claim **2** further including a low pressure working gas reservoir connected to said second tube main.

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